HABITAT

Photo courtesy of the National Park Service

EFFECTS OF WINTER RECREATION ON VEGETATION

Snowmobile, snowcoach, cross-country and telemark ski, snowshoe, and dog-sled activities occur throughout the winter and spring in the Greater Yellowstone Area (GYA). These activities occur on designated and/or groomed trails or as dispersed activities. Snowmobile activities often occur on constructed dirt and paved roadbeds. However, damage to vegetation has been observed in the GYA that is caused by winter recreational activities that occur off-trail. For example, branches of willows (*Salix* spp.) and sagebrush (*Artemisia* spp.) have been broken, and leaders have been removed from conifers.

POTENTIAL EFFECTS

There is little information available describing the ecological effects of snowmobiling and other winter recreational activities on vegetation. Research cited was completed in the 1970s and focused on assessing the impacts of snowmobile use on vegetation and snow characteristics in Minnesota and Canada.

SNOW COMPACTION

Snowmobile activities create trails as the vehicle compacts the snow. Other winter recreation activities also have the potential to increase snow compaction depending on the intensity of the activities. One traverse over undisturbed snow cover can affect the physical environment as well as damage plants (Wanek 1971). Compacted snow was calculated to have two to three times more density than uncompacted snow in Canada. Thermal conductivity of compacted snow was 11.7 times greater than uncompacted snow (Neumann and Merriam 1972).

SOIL TEMPERATURES

Soil temperature can also be affected by snowmobile compaction of snow. Wanek (1971, 1973) and Wanek and Schumacher (1975) observed that surface soil temperature under compacted snow was erratic and constantly lower than under uncompacted snow. Soils in the areas where snowmobiles traveled thawed later than where snowmobiles did not travel (Wanek and Schumacher 1975). This resulted in subsequent deep freezing that could affect the survival of many vegetative species. Wanek and Schumacher (1975) found that a large number of perennial herbs having subterranean organisms were subject to intracellular ice crystals which caused tissue dehydration. Soil bacteria, essential to the plant food cycle, were reduced 100-fold beneath a snowmobile track (Wanek 1971, 1973).

VEGETATION

Snowmobile activities damage vegetation on and along trails and in dispersed sites. The most commonly observed effect from snowmobiles was the physical damage to shrubs, saplings, and other vegetation (Neumann and Merriam 1972, Wanek 1971, Wanek and Schumacher 1975). Neumann and Merriam (1972) observed that compacted snow conditions caused twigs and branches to bend sharply and break. Stems that were more pliable bent and sprang back although the snowmobile track often removed bark from the stems' upper surfaces. Neumann and Merriam (1972) found that rigid woody stems up to one inch in diameter were very susceptible to damage. Stems were snapped off in surface-packed or crusted snow.

Snowmobiles often run over trees and shrubs tearing the bark, ripping off branches, or topping trees. In some trembling aspen (*Populus tremuloides*) areas, populations increased after snowmobiles disturbance. Deciduous trees that sucker may increase at first but then may decline if snowmobile activities remove the sucker shoots for several successive years (Wanek and Schumacher 1975). Studies (Neumann and Merriam 1972; Wanek 1971, 1973) indicated that conifers differed in tolerance of snowmobile traffic, and that pine species (*e.g.*, *Pinus contorta*) were less susceptible to damage than spruce species (*e.g.*, *Picea glauca*). Wanek and Schumacher (1975) found that young conifers were severely damaged by minimal snowmobile traffic. Depth of snow accumulation was the greatest factor contributing to snowmobile damage to conifers. Deeper snow tended to protect some species and age classes.

Herbaceous and woody plants exhibited varying responses to snowmobile activities. Most species were vulnerable to physical damage by snowmobiles. Twigs and branches of shrubby cinquefoil (*Potentilla fruticosa*) were broken more readily than aspen and buffalo berry (*Elaeagnus canadensis*). Some species increased while others decreased in number. Masyk (1973) found that productivity of grasses may be reduced in areas of snowmobile use. Wanek and Schumacher (1975) found that snowmobile activities set back the growth of some fast growing trees that normally would shade out some shrub species. Therefore, heliophytic shrubs proliferated.

In bog communities, snowmobile activities can result in frost penetrating more deeply, thereby delaying the spring thaw. Herbs and shrubs in these areas may exhibit population declines. Bog shrubs are highly susceptible to physical damage (Wanek 1973).

Early spring growth of some species may be retarded or may not grow under a snowmobile trail. This could potentially reduce the diversity of plants species available and/or reduce the quantity of available forage and the duration of forage availability for wildlife during the spring.

EROSION

Snowmobile activities may indirectly contribute to erosion of trails and steep slopes. If steep slopes are intensively used, snow may be removed and the ground surface exposed to extreme weather conditions and increased erosion by continued snowmobile traffic. The same results could occur when snowmobiles use exposed southern exposures. Because compacted snow generally takes longer to melt, trails are often wet and soft when the surrounding areas are dry. Consequently, these trails are susceptible to damage by other users during the spring (Masyk 1973).

In the GYA, the Potential Opportunity Areas in which vegetation is most affected include:

(4) Groomed motorized routes
(5) Motorized routes
(6) Backcountry motorized areas
(7) Groomed nonmotorized routes
(8) Nonmotorized routes
(9) Backcountry nonmotorized areas
(10) Downhill sliding (nonmotorized)

MANAGEMENT GUIDELINES

Adverse effects to vegetation are the result of cumulative factors. The impact of snowmobile activities on the physical environment varies with winter severity, the depth of snow accumulation, the intensity of snowmobile traffic, and the susceptibility of the organism to injury (Wanek 1973). Activities occurring on roadbeds and (most likely) trails are probably having little affect on vegetation as the areas are already compacted or disturbed. Effects of snowmobile activities on off-trail vegetation should be assessed at a landscape level.

Management or restriction of snowmobile activities should be considered in areas where forest regeneration is being encouraged as deformation of growth patterns was observed in conifers where leaders had been removed by snowmobile activities (Neumann and Merriam 1972). Management or restrictions should also be considered in fragile or unique communities, such as riparian and wetland habitats, thermal areas, sensitive plant species habitat, and areas of important wildlife habitat, in order to preserve these habitats.

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ISSUES

Photo courtesy of the National Park Service

EFFECTS OF DEVELOPMENT ON WILDLIFE

Increasing human development has a variety of impacts on wildlife and their habitats. The effects of development may act as additional adverse impacts to wildlife populations already affected by human activity. This may be important during winter when many wildlife populations are already nutritionally and energetically stressed.

The term "development" is most frequently used in reference to new home-building: subdivisions, ranchettes, and second homes. While this activity is possibly the most important factor affecting western wildlife, other types of development impact wildlife and habitats as well. For example, conversion of former wildlife habitat to agricultural use or livestock grazing land where wildlife is excluded and the construction of new roads or the expansion of existing road networks that create unsuitable habitats for wildlife are both types of development that may have important consequences for wildlife. Development, therefore, can be defined as any human activity that permanently reduces or removes habitat that is currently available to wildlife.

DEVELOPMENT IN THE GREATER YELLOWSTONE ECOSYSTEM

Although more than 80 percent of the Greater Yellowstone Area (GYA) is in public ownership, the approximately 20 percent of the area that is in private ownership (about 3 million acres) contains some of the area's most important wildlife habitats. These lands include ungulate winter ranges, riparian areas, and wetlands (Harting and Glick 1994). Since 1990, the region has experienced an overall growth rate of 12 percent, with some counties experiencing growth rates as high as 50 percent (Glick et al. 1991). As a result, home-building on rural private lands has increased tremendously (Glick et al. 1991), and nearly one-third of the region's private acres have been subdivided (Rasker and Glick 1994). As more people settle in the area, existing roads are increasingly unable to accommodate the larger volumes of traffic, and roads are often widened or new roads are built to link areas of development and use (Glick et al. 1998). The region's increasing population also contributes to increasing human use of the region's natural areas. For example, an estimated 25 percent of all visitors to Yellowstone National Park in 1990 were residents of the surrounding three states (National Park Service 1998).

GENERAL IMPACTS OF DEVELOPMENT ON WILDLIFE

DIRECT MORTALITY

Many human uses of developed landscapes are incompatible with wildlife use or presence and may result in direct mortality of wildlife that attempt to occupy those areas. Ungulates attempting to use historic winter range that has been converted to grazing land or agricultural use may not be tolerated because they compete with livestock for forage or cause damage to crops. Consequently, hunting seasons and/or areas may be designed to eliminate wildlife from those areas, or wildlife may be killed in special management actions. Large carnivores, such as bears and wolves, are generally not tolerated in proximity to areas of human habitation or use. Collisions with vehicles may also be a significant source of mortality for some wildlife populations. Between 1989 and 1995, an average of 117 wild animals were killed annually in vehicle collisions in Yellowstone National Park (Gunther et al. 1997). Severe winters may increase the number of road kills when wildlife seek lower elevation, low-snow areas, which are where roads tend to be built. Many animals also use roads and groomed trails as travel corridors when snow becomes deep and restricts movement. During the last ten years more than a dozen animals, including bison, coyotes, elk, and moose, have been killed in collisions with snowmobiles in Yellowstone National Park (M. Biel, Yellowstone National Park, personal communication).

REDUCTION OR ELIMINATION OF WINTER RANGE

Most ungulate species in the Rocky Mountain West rely on distinct summer and winter ranges, taking advantage of seasonally available forage at higher elevations during the summer and returning to areas of lower snow accumulation during the winter where there is greater access to forage. These low-elevation winter ranges, however, tend also to be favored by humans for settlement, agriculture, and road-building (Glick et al. 1998). Human occupation of winter home ranges may lead to decreased reproduction or increased mortality of ungulates that traditionally use those areas by decreasing the amount or quality of forage or by increasing disturbance levels (Mackie and Pac 1980, Houston 1982, Smith and Robbins 1994). Because ungulates tend to concentrate in areas of limited size during the winter, loss or degradation of even small portions of winter range have consequences far greater than loss of similarly sized portions of summer range (Mackie and Pac 1980).

FRAGMENTATION OF HABITATS AND POPULATIONS

Development frequently has the effect of fragmenting formerly large or widespread populations into smaller sub-populations isolated from one another to varying degrees. Fragmentation may also mean that connections to supplemental habitats or seasonal ranges are degraded or lost (Wilcove et al. 1986, Dunning et al. 1992). The ability of individuals to recolonize areas or supplement declining populations may be lost when habitat connections between sub-populations are degraded or severed (Wilcove et al. 1986). Because of these factors, populations in isolated natural areas tend to be small (Wilcove et al. 1986, Dunning et al. 1992). Small population size and lack of habitat options generally result in a lowered ability to withstand disturbance or natural environmental fluctuations and can result in local extinction of wildlife populations (Wilcove et al. 1986).

DISTURBANCE

Increasing numbers of humans present in the region have meant an increasing amount of human activity in areas used by wildlife. Human activity may prevent some wildlife species from taking advantage of foraging opportunities within their home ranges, even where habitats remain intact. Green (1994), for example, found that roads and traffic in Yellowstone may diminish or prevent bear use of some winter-killed ungulate carcasses. Disturbance that occurs in winter or other periods of energetic stress can be of particular concern. During the winter, many animals reduce their activity, and therefore energy expenditure, to compensate for reduced energy intake, a result of limited quantity and quality of available forage (Telfer and Kelsall 1984). Aune (1981) found that elk, bison, mule deer, and moose in Yellowstone National Park developed crepuscular activity patterns and showed altered patterns of movement and habitat use in response to winter recreationists. Behavioral and physiological responses to continuing harassment in the form of noise or certain types of human presence can shift an animal's energy balance so that more is expended than is taken in, which results in decreased survival or reproduction success (Anderson 1995).

OTHER IMPACTS

In addition to the examples listed above, development can have a variety of other impacts on wildlife. Subdivisions, agricultural areas, clearcuts, or roads can block migration or movement routes, resulting in the inability of animals to reach important habitat components such as breeding or nesting areas, seasonally available forage, or refuges from predation or disturbance (Wilcove et al. 1986, Dunning et al. 1992). Development can alter habitats making them more favorable for generalist species that out-compete specialists in their former habitats. White-tailed deer, for example, appear to be replacing mule deer near developed areas in the Gallatin Valley (Vogel 1989). Although attempts have been made in recent years to restore the role of fire in natural areas, the presence of nearby human developments means that fire suppression will continue on large portions of many protected areas. Long-term fire suppression leads to changes in vegetation, which may impact wildlife in diverse ways (Houston 1982). Ground disturbance by humans has increased the presence and distribution of various species of exotic vegetation that may out-compete important native forage species. Cheatgrass (*Bromus tectorum*), for example, has invaded large portions of western rangelands. While this species greens early and may be of some spring forage value to ungulates, it may ultimately reduce the availability of winter forage by out-competing other, later maturing species (Houston 1982).

IMPACTS TO INDIVIDUAL SPECIES

ELK

Humans are increasingly occupying elk winter range in the GYA. In the Jackson Hole area in the early part of this century, human occupation of elk winter range contributed to the death by starvation of thousands of elk in the valley (Anderson 1958, Robbins et al. 1982). Actions taken to mitigate for human usurpation of winter range, however, have created other problems and led to complex management issues requiring often controversial solutions.

In 1912 Congress set aside a portion of the remaining valley bottom as the National Elk Refuge, and in the 1950s winter feeding of elk on the refuge and on other state-run feedgrounds in Wyoming became policy (Anderson 1958). Because the available winter range is restricted in size and the feeding program was designed to maintain a relatively high elk population, a sometimes controversial hunting program designed to control the size of the elk population was necessary (Smith and Robbins 1994). Maintaining a large number of elk in a geographically restricted area has also contributed to the continued presence of brucellosis in the herd (Thorne et al. 1991). Brucellosis in cattle has been the subject of an intensive state and federal eradication program, and the presence of the *Brucella abortus* bacteria in wildlife in the GYA has been the subject of much controversy in recent years, complicating management of both bison and elk.

Elk in the northern portion of the GYA do not present such perplexing management problems, but are nevertheless faced with decreasing availability of winter range. Historical accounts indicate that large numbers of elk wintered in the Yellowstone River valley north of Gardiner, Montana, and summered in the mountain ranges north of the park (Houston 1982). Settlement and agricultural development in the valley bottom have reduced the number of elk that are year-round residents in this area to slightly more than 1,000 animals.

These animals winter along the margins of the valley (Houston 1982). In recent years, range expansion of the northern Yellowstone elk herd during the winter has been of some concern to wildlife and land managers (T. Lemke, Montana Fish, Wildlife and Parks, personal communication) and private landowners. During some winters, elk use both public and private lands designated for summer livestock grazing, lessening the forage available to cattle. In severe winters, elk often depredate winter hay stores on private lands in the valley bottom. Any factors decreasing the quality or availability of the winter range on public lands and protected areas will only increase the magnitude of these problems and increase pressures on the elk population.

BISON

Bison management in the GYA has been the subject of major controversy, largely because both the Yellowstone and the Jackson bison herds have been exposed to brucellosis. Brucellosis is a disease of cattle that has been the subject of an intensive state and federal eradication program since the 1930s. Because neither Yellowstone nor Grand Teton national parks encompass a complete ecosystem for most ungulates, including bison (Keiter 1991), animals migrate out of the parks in the winter. Historically, during severe winters, Yellowstone bison probably migrated to lower elevation winter ranges in the Yellowstone River valley north of the park (Meagher 1973) and, possibly, also to winter ranges in the Madison Valley. The bison population in Yellowstone was driven to near-extinction by the beginning of the twentieth century (Meagher 1973), and during the subsequent decades when the population was recovering and heavily managed, most of the historic winter range outside the park boundary was settled and developed by humans. Much of the land adjacent to the parks is used for cattle grazing and ranching for all or part of the year. Because of the concern that infected or exposed bison could transmit brucellosis to cattle (Thorne et al. 1991) and because bison may compete with cattle for forage or destroy fences or other private property, a very complex and controversial set of management plans and policies have evolved for Yellowstone's bison.

Bison from Grand Teton National Park migrate to the National Elk Refuge and take advantage of the winter feed provided for elk. Both elk and bison on the refuge have been exposed to brucellosis, and concerns exist regarding potential contact between bison and nearby cattle (Thorne et al. 1991). The result, as in Yellowstone, is a controversial management scenario that continues to be the subject of debate and discussion.

MULE DEER

Mule deer populations in portions of the GYA have declined dramatically in recent years, and human development on winter range may be a contributing factor. Mule deer numbers declined as subdivisions and human activity increased on historic winter range northeast of Bozeman, Montana (Mackie and Pac 1980, Vogel 1989). Individual mule deer, particularly adult does, exhibit a high degree of fidelity to the same seasonal home ranges (Garrott et al. 1987, Mackie and Pac 1980). Because of this, it has been estimated that loss of one square mile of primary winter range along the foothills of the Bridger Range could result in loss of up to 30 percent of the southern Bridger Range mule deer population (Mackie and Pac 1980). Disturbance associated with increased housing development may cause deer to become more nocturnal (Vogel 1989, Dasmann and Taber 1956). This shift in activity pattern could increase energetic demands on deer and other animals during winter when they are nutritionally and energetically stressed by causing them to forage during colder and more severe nighttime weather (Aune 1981, Vogel 1989).

Impacts may differ between migratory and resident herds. Nicholson et al. (1997) found that migratory mule deer are much more vulnerable to human disturbance than are resident animals. This may have serious implications for other migratory ungulates as well, including elk that migrate in and out of Yellowstone and Grand Teton national parks.

PRONGHORN

The northern Yellowstone pronghorn herd, at present numbering roughly 250 animals, is a remnant of a population that historically occupied the Yellowstone River Valley between Gardiner and Livingston, Montana (Barmore 1980). This herd may have been contiguous with pronghorn populations farther east in Montana. Pronghorn were eliminated south of Livingston prior to 1920 (Skinner 1922, Nelson 1925). Consequently, the Yellowstone pronghorn population is isolated. It is estimated that the herd has approximately 18 percent chance of extinction in the next 100 years (Goodman 1996) because of its small size and complete isolation from other pronghorn populations. Currently, pronghorn in Yellowstone have limited access to private lands north of the park boundary and, therefore, little buffer against severe conditions that occur at times within the park. Severely limited winter range may have contributed to a recent decline in numbers in this population.

The Jackson Hole segment of the Sublette Antelope Herd may be at risk from development. This population segment exhibits seasonal migrations from Grand Teton National Park south to Interstate 80 near Rock Springs, Wyoming. Oil and gas development on critical winter ranges of these antelope, coupled with increasing pressure on naturally restricted migration corridors, threatens such movement (Doug McWhirter, personal communication).

MID-SIZED CARNIVORES (MARTEN, LYNX, AND WOLVERINE)

Mid-sized carnivores, such as marten, lynx and wolverine, are particularly vulnerable to the effects of habitat fragmentation. The current presence and distribution of lynx and wolverine in the GYA is likely influenced by development and habitat fragmentation that is the result of logging and road-building. The patches of habitat remaining may not be of sufficient size to guarantee an adequate prey base to sustain populations of these species (Buskirk and Ruggiero 1994, Lyon et al. 1994). The quality of smaller habitat patches may also be degraded as a result of influences from edge species and other disturbances occurring at or near patch boundaries (Wilcove et al. 1986).

Marten, and to some extent lynx, require significant amounts of late successional stage (old-growth) forest components in their home ranges (Buskirk and Ruggiero 1994, Lyon et al. 1994). The appearance of early successional stage vegetation and structure in a mature forest that is a result of logging or subdivisions combined with easier access via summer roads or groomed snowmobile trails may increase the number of generalist predators, such as bobcats and coyotes, that compete with marten, lynx, and wolverine (Lyon et al. 1994). Dispersal and migration of marten may be largely dependent on the presence of heavily vegetated riparian areas or connected patches of mature forest (Lyon et al. 1994). Development of any kind may alter or remove these corridors, isolating populations, decreasing stability of the prey base (Buskirk and Ruggiero 1994), and increasing vulnerability to environmental pressures. Disturbance by humans is of concern during winter, when small prey that is utilized by martens may be less available because of snowcover (Buskirk and Ruggiero 1994). Woody debris allows marten to access prey beneath the snow surface (Buskirk and Ruggiero 1994), and its loss along with the compaction of snow by vehicles may have negative impacts on marten populations by decreasing available food.

LARGE CARNIVORES

Grizzly bears in the GYA are effectively isolated from other populations. Maintenance of a stable or increasing bear population depends solely on reproduction by resident females (Knight and Eberhardt 1985). Most grizzly bear deaths in the GYA between 1973 and 1985 were human caused (both legal and illegal) and were clustered around gateway communities or other developments near Yellowstone National Park. Various attractants such as garbage, orchards, and outfitter camps tend to draw bears into conflict situations with humans, frequently resulting in bear mortality (Herrero 1985, Knight et al. 1988). Developments can function as population sinks for bears and other animals, potentially creating a drain on already stressed populations.

Humans are responsible for most mortalities experienced by the newly reintroduced wolves in the GYA (Phillips and Smith 1997). Deaths occurred by collisions with vehicles, poaching, or management removals following wolf depredation on domestic livestock. Development on the borders of Yellowstone puts wolves in jeopardy if they travel outside of protected areas.

Factors that stress ungulate populations, and thus increase their vulnerability to predation or other types of mortality, may benefit large carnivores and scavenger species in the short-term. However, if such factors lead to a long-term reduction of the ungulate populations, carnivore and scavenger species may be adversely affected through a reduction in the total amount of prey or carrion biomass available to them.

OTHER SPECIES

Little is known about the several owl species inhabiting this region (Holt and Hillis 1987), but owls may be particularly vulnerable to disturbance during winter when prey species are less vulnerable due to snowcover. Guth (1978) found that bird density and diversity increased in developed sites, but that the species present represented a greater percentage of common and widespread species; several rare forest species were absent. Amphibians, reptiles, small mammals, and fish are likely to be affected indirectly and more subtly by development and recreation than large mammal species (Cole and Landres 1995). Impacts to these smaller species, however, may have long-term impacts to overall wildlife community structure and function by altering prey base, plant community dynamics, and animal distribution (Gutzwiller 1995).

MANAGEMENT GUIDELINES

It has been stated that a critical role of parks and other protected natural areas is to compensate or correct for the influence of modern man on ecosystem processes (Houston 1982). Few wildlife populations in the GYA are restricted entirely to protected areas (Keiter 1991), however, and protected areas are also subject to pressures accompanying development. Many effects of development, such as removing winter range, blocking migration routes, disturbance caused by human activity, and reducing quantity or quality of forage species, carry particular impacts during the winter when animals are nutritionally and energetically stressed. In view of these observations, the following recommendations may help to reduce or mitigate the impacts of development on wildlife:

- Minimize future development and, where possible, reduce current levels of development and their concomitant impacts in natural and protected areas.
- Place any necessary new developments within or immediately adjacent to existing developments so that human impacts are clustered, allowing larger portions of relatively pristine habitat to remain intact. The location of future and existing activities and developments should be carefully considered to avoid disturbing or removing important habitat components.
- Intrusive, noisy, or otherwise potentially disturbance-causing human activities should be avoided during the times of year when wildlife populations are already under severe environmental and/or physiological stress. Winter is a critical stress period for ungulates, and birthing/nesting time is critical for a wide variety of species.
- Cooperation among adjoining land management agencies and with landowners adjacent to protected areas should be strengthened so that habitats spanning more than one jurisdiction are managed or conserved as intact systems.
- Where possible, ungulate winter range should be protected or access acquired for wildlife to mitigate for existing development levels.
- Research and monitoring programs on a wide variety of species are vital to accomplishing most of the recommendations above. Information on seasonal habitats, migration routes, nesting or birthing sites and areas, and timing of animal activities are necessary in order to avoid significant impacts of development on wildlife populations.

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Energetic Costs of Wildlife Displacement by Winter Recreationists

Herbivores (plant-feeding animals) often function at an energy deficit during the winter months. Snow impairs their access to food, increases the energy cost of gathering the food, and increases the cost of locomotion. Because plant growth has stopped, except in thermal areas, the food value of plants is often low unless the animal has access to points of energy storage such as buds. Snow characteristics and depth are controlling influences upon the winter distribution of plant-feeding animals. In the northern Rocky Mountains, limited winter access to food has led to the selection of species that have an enhanced ability to store energy. This energy store provides a large proportion of the energy necessary to carry on animal functions through the winter. The rest of the energy must be gathered from winter range areas. A consequence of the limited energy stores and limited food availability is that disturbance of animals by winter recreationists may result in increased energy expenditure with adverse effects upon the survival of the animal, its ability to give birth to and raise viable offspring, and the maintenance of the social dynamics of the population. At the same time, winter recreation produces packed snow travel routes that may enhance energy conservation by the animals. Such trails include the single-file trails produced by the flight of animals disturbed by recreationists, cross-country ski and snowshoe trails, and groomed road and trail systems provided for snowmobile use.

To provide guidelines for the management of winter recreationists so that undue depletion of the energy supplies of Yellowstone herbivores can be avoided, it is necessary to analyze animal response to humans at the individual level and the group level. Factors that affect and induce variability in the responses of animals are discussed along with energetic implications.

Mechanisms of Response

Sensory Links to Human Intrusion

The response of animals to intruders begins with the sensory envelope of the animal. The major senses involved in this response are those of sight, olfaction, and hearing. Each of these senses has its own threshold, character, and pattern of response that may vary between the different species as well as between the different populations of each species. One of the concepts that is of use in understanding these responses is the Weber-Fechner law of psychosensory perception. This rule demonstrates that a sensory stimulus must change by a fixed proportion in order for an animal to recognize that the stimulus has changed. This is called the “just noticeable difference” (JND) or Weber-Fechner constant (Withers 1992, Randall et al. 1997). Some responses to these sensory stimuli, such as moving or changes in posture, have energetic implications. Other responses, such as changes in heart rate, may or may not have energetic implications. Bighorn sheep and elk respond to humans that approach to within 55 yards by increases in heart rate (MacArthur et al. 1979, Cassirer and Ables 1990). Because cardiac output is a function of the stroke volume of the ventricles as well as the heart rate, an increase in heart rate does not necessarily mean an increase in cardiac output nor does it always mean an increase in energy consumption (Ganong 1997).

Vision is a major sense for most animals, although it may be less important in relative terms to them than it is to humans. The JND for vision is typically about 0.14, meaning that stimuli must change by 14 percent in order for the change to be detected. The range at which wild, large mammals typically show some sort of avoidance or suppression of activities is typically about ½ to 1 mile in open, relatively flat terrain (Ward et al. 1973, Lyon et al. 1985, Cassirer and Ables 1990). This zone of visual interference of use is reduced at night and under conditions of vegetative cover density and height that block vision. An energetic implication of this is that use of the winter range in this zone of relative exclusion is reduced to about half its normal level (Lyon et al. 1985). Bighorn sheep, in some circumstances, tolerate closer intrusion, which is probably related to both the limited nature and greater security furnished by their rough and broken habitat. The habituation state of the animals also affects their response and will be discussed later. While partial color vision has been demonstrated in some non-primate mammals, it has not been conclusively demonstrated in most mammal species. (Experiments on color vision, properly controlling luminance, saturation, and brightness at all visible light wavelengths, are difficult to do and have not been accomplished for most park mammals.) Thus, color does not seem to be of importance in triggering energetically expensive behavior. It is believed that some species, such as bighorn sheep, have specializations for high acuity of vision, while other species excel at detecting movement. Breaking the visual stimulus by crossing a ridgeline or other visual barrier is an important factor in responses to disturbance (Dorrance et al. 1973, Lyons et al. 1985, Cassirer and Ables 1990) and, thus, can be a significant factor in regulating energy expenditure.

Smell or olfaction is an important sensory element for mammals. Odors can be carried some distance by air currents and may be absorbed on snow and vegetation. Olfactory sensing of chemical odors has a high JND (about 0.3) indicating that only fairly substantial changes in odor can be noted. The deposition of olfactants on snow and plants has the potential for extending sensory responses for considerable periods of time. Accommodation to odors occurs rapidly, and mammals do not appear to show avoidance of snowmobile pollution in the snow (Aune 1981). Thus, the persistence of snowmobile pollution does not seem to be an important factor affecting energetics. Accommodation to one odor does not necessarily mean suppression of the ability to detect others. Thus, the olfactants deposited by snowmobiles (Aune 1981) are unlikely to interfere with the detection of predators by odor. Sensitivity to individual odors varies widely and differs between species. While olfaction is an important communication pathway, it appears to be unimportant in triggering highly energetic behavior after the rut is over but, like hearing, may reinforce visual response (Cassirer and Ables 1990).

Hearing has a JND of about 0.15. While several studies (Dorrance et al. 1973; Ward 1977; MacArthur et al. 1979, 1982; Stockwell et al. 1991) have focused upon the effect of relatively loud noises on animal behavior, it is often the relationship of a sound to the background noise level that is significant. Vegetation is highly effective in absorbing sound (Aylor 1971a and b; Harrison 1978). The sound level from an idling pickup truck was measured at 50 db about 90 yards from the vehicle in an open environment and at 70 yards in a mature forest in the Yellowstone area (Anderson 1994). Sound levels of 45 to 65 db at the point of animal toleration have been reported for snowmobiles in some studies

(Bury 1978). Better muffling and design have reduced snowmobile noise levels since these studies were done. The berms of snow along groomed snowmobile trails also tend to absorb and deflect sound.

The channeling of sound by inversions and dense air layers is common in mountain environments. A sound that is not heard near its source may occasionally be carried and perceived ½ mile or more distant without having been heard at intermediate distances. Air currents are also important in conveying sound. Cassirer and Ables (1990) observed that wind blowing toward animals increases movement away, suggesting that smell and hearing tend to accentuate the response triggered by vision. Animals may be expected to show some response at sudden or erratic sounds of 1 to 3 db in the quiet 30 db environment of a forest while requiring higher sound energies to produce a response if they are in a 60 db environment along a busy road. Constant noise levels are readily accommodated for and, as mammal populations on jet airports and airbases (Weisenberger et al. 1996) demonstrate, even predictable loud sounds can be ignored by animals. However, unpredictable noise can affect range utilization and movements of elk (Picton et al. 1985).

INDIVIDUAL RESPONSE

The energetic response of individual animals to human intrusion varies widely. One question that arises in Yellowstone is: where on the wild to domesticated continuum do various subpopulations fall as habituation is a physiological process with energetic consequences. Are the elk within the limits of the Mammoth development wild or domesticated? If they are domesticated, no energetic cost of human presence is involved. The chronically elevated resting heart rates of these animals (Cassirer and Ables 1990) indicate that this subpopulation is habituated rather than domesticated. Habituation reduces the physiological cost of dealing with an environmental stressor, but it seldom eliminates the cost entirely. This habituation has involved learning to ignore the large auditory and olfactory stimulation imposed by human activities while learning to rely almost entirely upon sight. Visual responses have been modified to permit human intrusion as close as 16–22 yards without eliciting flight behavior.

In the absence of other data, we can use weight and heart rate comparisons between the Lamar and the Mammoth elk to make a minimum rough estimate of the energetic differences between the two areas (Cassirer and Ables 1990). It appears that the direct energy cost for habituation and its prolonged alert status that is required for daily living in Mammoth is about 2 percent more than the cost of living in the Lamar. However, the more accessible and better forage provided by the green lawns of Mammoth results in a net daily energy intake in the range of 6–7 percent more than that in the Lamar. This gives the Mammoth elk a net advantage of about 4.5 percent. Year-to-year variations in winter severity probably have more effect on the Lamar animals than on the Mammoth elk. If calf production differences are included, the net energetic advantage of the Mammoth elk might be as much as 8 percent per day during the fall and winter months. Because this is based upon fall calf/cow ratios, the effects of a higher predation rate upon the calves in the Lamar is not considered. This failure to consider differences in predation would tend to overestimate the energy difference between the two areas. It should be noted that biological variation suggests that not all individuals in a population habituate equally as well to humans, thus, we would expect a population to contain a segment that habituates easily and another segment that shows more extreme avoidance behavior.

The travel routes of humans, such as roads and heavily used trails, are usually avoided to some extent by animals. A rough estimate suggests that perhaps 10 percent of the northern Yellowstone winter range has had its large herbivore-use capacity reduced by 50 percent (Lyon et al. 1985) due to use of the northeast entrance road between Mammoth and Cooke City. This road is a permanent feature of the environment, but the effects of it can be seen in plots of animal distribution along the route. This implies a lost-opportunity cost of perhaps 5 percent of the total energy supply of the range. It is unlikely that this "highway" effect has reduced the capacity of the Gibbon–Firehole range to the same degree. The nature of the geothermal range, its topography, high habituation levels of animals, and the lower energy statuses of the animals tend to reduce some of these impacts.

The energetic effects of disturbance are affected by seasonal changes in the energy balance of the animals, snow conditions, and distribution as well as annual variation in the conditions. The usual pattern of energy regulation in animals is to expend the energy consumed in the last meal rather than to consume energy to replace the energy that has been expended since the last meal (Hainsworth 1981). Thus, as energy stores drop, the tendency to conserve energy increases (Moen 1976), which will lead to a decrease in flight initiation distances upon being disturbed. This is the general pattern seen in flight initiation distances during the course of a winter. Research should be conducted to determine if disturbance of the animals results in increases in the length or frequency of feeding bouts, which would suggest some replenishment of energy stores. If food intake does not increase, a more critical effect upon the animals is implied.

Early in the winter, snow conditions tend to be better under the forest canopy than out in the open. The cold winters of Yellowstone encourage the ablation of snow from the forest canopy to a unique degree (Skidmore et al. 1994). This process can prolong the use of forest cover by the ungulates, which reduces the intensity of auditory as well as visual disturbance and its energetic consequences. The group size of elk tends to be smaller in the timber and their flight distances shorter, which results in less disturbance impact.

It is clear that the energetic expenditures of animals must be considered on the basis of their habituation status and energetic status as well as on snow depth. Calculations were performed for each of three different range situations: the Mammoth habituated population, the Lamar population, and the Gibbon–Firehole population. Estimations were calculated for a 590 lb. adult elk, a 200 lb. calf elk, a 150 lb. adult mule deer, and a 1,200 lb. bison under both early winter snow conditions and the dense snow conditions of late winter. The daily activity budget of elk was used as the activity budget for all of the ungulates (Nelson and Leege 1982). A density of 0.2 was assumed for the early winter powder-snow conditions, and a density of 0.4 for late winter compacted snow. Comparative calculations were done for no snow and for snow depths of 30 percent and 58 percent of brisket height. These depths were selected on the basis of the knee (carpel) length (Telfer and Kelsall 1984). Energy expenditures go up at exponential rates when snow depths are above the knee, conditions that are generally not tolerated by the animals. Parameters concerning energy expenditure were obtained from Parker et al. (1984) and Wickstrom et al. (1984). Behavioral responses to disturbances were obtained from Aune (1981), Cassirer and Ables (1990), and Freddy et al. (1986). The energetic expenditure due to changes in the "alert" behavioral status of the elk was estimated using Cassirer and Able (1990). The percentages expressed are for a total estimated daily energy budget of 7,072 kcal. for a 590 lb. adult elk; 2,861 kcal. for a 200 lb. calf elk; 2,243 kcal. for a 150 lb. adult mule deer; and, 11,167 kcal. for a 1,200 lb. bison. The cost of a single flight for a habituated adult elk increased the 7,072 kcal. daily energy budget between 3.2 and 7.1 percent, depending upon snow conditions, for an escape distance of 0.3 mile. The longer escape distance of 1.2 miles reported for the Lamar area (Cassirer and Ables 1990) gave energetic increases of 8.7 to 24 percent on level terrain. If the elk in the Lamar runs uphill for 60 percent and downhill for 20 percent of the time over a typical escape course (Cassirer and Ables 1990), energy costs may increase by 40 percent over the cost estimated for level terrain. High single-escape costs of more than 10 percent probably could not be tolerated by the elk throughout the entire winter season. Behavioral adjustment would probably be made to use slopes with less snow, shorter escape distances, or habituation. What might be perceived as a greater tolerance of the animals to disturbance as the winter season progresses might, in reality, be the result of these energy conservation responses as well as the influence of the lower energy status seen in late winter. The much shorter escape distances reported for the Firehole area may be reflective of the much more marginal energy status of these elk (Pils 1998) as well as habituation. The overall energy expenditure of the 200 lb. calf elk for the various situations averaged about 16.3 percent more than that of adults. The shorter legs of the calves dramatically increase escape costs in deep snow. The number of disturbances or close encounters necessary to produce habituation is unknown, but probably exceeds two per day. Habituation to cars or snowmobiles following highly predictable paths readily occurs. Habituation to the less predictable occurrence and movements of cross-country skiers and individuals on foot is a more difficult situation (Bury 1978, Schultz and Bailey 1978, Aune 1981, Ferguson and Keith 1982, Freddy et al. 1986).

For a habituated mule deer, the daily energetic expenditure of a single intrusive event is estimated to increase the daily energy budget of 2,861 kcal. by 2.5 to 5.9 percent. In the Lamar, responses increased energy expenditures 4.7 to 17 percent as compared to a range of increase of 1.8 to 2.2 percent for the Gibbon–Firehole area. The responses of mule deer were based upon the observations of Aune (1981) and Freddy et al. (1986).

Little information is available concerning the energetics of bison. Specific information concerning bison was obtained from Telfer and Kelsall (1984) and combined with general information covering large mammals in general (Parker et al. 1984, Wickstrom et al. 1984, Withers 1992). Personal observations suggest that bison are relatively unresponsive to human intrusion. Thus, the elk response data from the Gibbon–Firehole was used in the calculations. A single disturbance produces an increase in daily energy expenditure of 1.5 to 2.1 percent more than the 11,167 kcal. daily energy budget. The low, late-winter energy levels of bison may increase their tendency to allow close approach by humans and increase visitor hazards.

Failure to produce viable offspring has been suggested as a logical outcome of imposing high-energy disturbance stress upon animals. In an experimental situation, Yarmaloy et al. (1988) reported that it required direct targeting of a specific mule deer with a harassing all-terrain vehicle (ATV) repeated 15 times (averaging nine minutes each time) during October to induce reproductive disturbance. Deer not specifically targeted habituated to the ATVs with little apparent notice and suffered no reproductive consequences. No information is available to indicate the frequency of disturbance throughout the winter by recreationists or predators of individuals or individual groups of animals.

GROUP RESPONSE

"Single filing" is a major group response that affects the energetics of response to winter recreationists and the situations created by them. Single filing reduces the energy costs of travel through snow to a major degree. While the parameters of this type of movement have not been defined in the literature, unpublished field observations suggest that by the time the tenth animal passes along a trail, the energetic costs will be reduced to near the base level for locomotory activity. While short-distance flight movements are often individual, group movements will usually coalesce into single files for the longer travel distances, such as is seen in the Lamar area.

Of course, the single-file animal trails are not the only packed trails in the park. Wildlife will sometimes use foot trails as well as the groomed snowmobile trails to facilitate their movements. While cross-country ski trails or snowshoe trails are usually not attractive to the large mammals (Ferguson and Keith 1982), groomed or heavily used ski trails may be attractive to them.

The monthly average snow depths on the various portions of the Firehole–Madison winter ranges were from 6.5 to 10 inches in the severe winter of 1996–97 (Dawes 1998). In estimating energy consumption, let us assume travel through 18 inches of dense snow, which is about the maximum tolerated depth based upon the brisket height of an adult elk and is a slightly more extreme depth for the shorter legs of calf elk and bison. If we further assume that the usual daily activity budget of an ungulate involves 0.6 mile of travel, we can calculate that an adult bison will save about 4.3 percent of a normal daily energy budget by using the groomed roads. At snow depths of 9.5 inches, more comparable to that seen on the winter range, the savings during the December through March deep-snow period would be about 1.2 percent of the daily energy budget or an accumulated 1.4 days for the normal 11,167 kcal. daily energy budget. If we postulate a 22-mile migratory movement from the Fountain Flat area to West Yellowstone through 18 inches of dense snow, the groomed trail savings will be the equivalent of 1.66 days of the normal energy budget for a 1,200 lb. bison.

An adult elk has a smaller body size and longer legs than a bison. The daily savings for an elk under deep, dense snow conditions is estimated at 3.4 percent of the daily energy budget and 1 percent for the more normal snow conditions of 9.5 inches. The savings under the 18-inch, dense snow conditions would be about 1.2 days worth of energy, assuming the conditions persisted for the 121-day December through March period or 47 percent of the cost of maintaining a pregnancy from conception to the end of March. A 22-mile migration over a groomed trail would produce energy savings of about 1.1 days for the 7,072 kcal. daily energy budget equivalent under the deep, dense snow conditions. The energy savings experienced by the shorter limbed 200 lb. calf elk are estimated at 4.9 percent of the 2,861 kcal. daily energy budget for the 18-inch, dense snow conditions and 1.5 percent for the 9.5 inch snow levels. This is equivalent to a gain of about 1.8 days supply of energy for the 121-day winter period.

PREDATORS

The interaction, if any, between winter recreational disturbance of ungulates and predation is unknown. A range of effects, from enhancing predation effort by increasing energy depletion and sensory confusion in the ungulates to the use of humans as protective cover by ungulates, can be hypothesized. The medium to large predators in Yellowstone have lower foot loadings than the ungulates and, thus, can move over the snow much of the time. This serves to compensate for their shorter brisket heights. Although usually regarded as wilderness animals, wolverines will include clear-cut areas in their home ranges, and it has been speculated that later winter snowmobile use might affect habitat use (Hornocker and Hash 1981). Unpublished observations indicate that wolverines will use areas of terrain subjected to moderate uncontrolled snowmobile use (J. W. Williams, Montana Fish, Wildlife and Parks, personal communication). Wolves, foxes, coyotes, wolverines, and lynx are known to use roads and snowmobile and other trails when traveling (Neumann and Merriam 1972, International Wolf 1992, Ruggiero et al. 1994). The frequency of ungulate disturbance by either predators or humans is unknown. Avoidance of areas of intense human use by predators has also been reported.

MANAGEMENT GUIDELINES

- Make human use of wintering areas as predictable as possible. This can be done by restricting access and the timing of the access. Preferably, skiing should be restricted to mid-day hours and designated paths.
- Humans on foot should not approach wildlife, even those that are habituated, any closer than 20 yards; preferably, not closer than 55 yards.
- Escape breaks in the snow berms along plowed roads and groomed trails should be made to permit animals to easily leave the roadway. Crossing a deep snow berm often causes a brief but intense expenditure of energy. Animals in late winter condition may have considerable difficulty in producing the brief intense energy flow necessary to meet these demands.
- Any winter-use trails in close proximity (less than 700 yards) to major wildlife wintering areas should be screened by routing to put the trail behind ridgelines and vegetative cover.
- Low speed limits should be set on roads and snowmobile trails, particularly in winter range areas.
- Information, past and future, concerning snow depths, snowmobile use, and the reproductive ratios of each species and each major population segment should be collected and analyzed for indications of negative effects on wildlife.
- Information on the daily activity budgets and daily movement budgets of bison are lacking. This information could give considerable insight into the impacts of winter recreation upon this species and should be collected.
- Public information efforts concerning the winter ecology of animals should be conducted. Information concerning the actual frequency of disturbance is desirable for more definitive estimates of the energetic impacts resulting from winter recreationists. Information concerning the interaction of this disturbance with that produced by wolves is desirable.

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IMPACTS OF TWO-STROKE ENGINES ON AQUATIC RESOURCES

Human recreational activities impact aquatic resources directly and indirectly. Winter recreation affects aquatic organisms mainly by indirect impacts due to pollution. Two-stroke engines can deposit contaminants on snow, leading to ground and surface water quality degradation, which subsequently may impact aquatic life.

LIFE HISTORY AND STATUS

Fish are important components of aquatic ecosystems and are important links in the transfer of energy between aquatic and terrestrial environments. Native and non-native fish, aquatic microorganisms, insects, and crustaceans integrate into a complex aquatic community. In Yellowstone National Park there are 12 native and 6 introduced fish species (Varley and Schullery 1983). In the Yellowstone area and the Rocky Mountain region, trout and other salmonids (Family Salmonidae) are the major game species. Native fish include Yellowstone cutthroat trout (*Oncorynchus clarki bouvieri*), westslope cutthroat trout (*O. clarki lewisi*), Snake River cutthroat trout (*O. clarki*), arctic grayling (*Thymallus articusi*), mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catostomus platyrhnchus*), longnose sucker (*C. catostomus griseus*), Utah sucker (*C. ardens*), mottled sculpin (*Cottus bairdi*), redside shiner (*Richardsonius hydrophlox*), Utah chub (*Gila atraria*), longnose dace (*Rhinicthys cataractae*), and speckled dace (*R. osculus*). Non-native fish species include rainbow trout (*O. mykiss*), brown trout (*Salmo trutta*), eastern brook trout (*Salvelinus fontinalis*), lake trout (*S. namaycush*), and lake chub (*Couesius plumbeus*).

Some fish species are becoming endangered as populations decrease from human exploitation, environmental degradation, and competition and predation from exotic or introduced species. While no fish species in the Yellowstone area are listed under the Endangered Species Act, the fluvial Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout are considered species of concern in Wyoming, Montana, and Idaho. All three species have been petitioned for federal listing under the Endangered Species Act (50 CFR Part 17), and it has been determined that listing of the fluvial Arctic grayling as endangered is warranted but precluded at this time. Determinations for the other two species are pending.

HUMAN ACTIVITIES

Much of the existing literature relating to impacts on aquatic biota has been restricted to outboard engines on boats that discharge a variety of hydrocarbon compounds directly into the water column (Bannan 1997). However, the discharge of snow machine exhaust directly into accumulated snow may provide a corollary. For example, emissions from snowmobiles have been implicated in elevated lead contamination of snow along roadsides (Ferrin and Coltharp 1974). Although lead is no longer a concern, hydrocarbons are still deposited on the top layer of snow along snowmobile trails (Adams 1974).

Contaminants from two-cycle engine exhaust include carbon monoxide, hydrocarbons, Methyl-*tert*-butyl ether (MTBE), Nitrous oxides (NO_x), and particulate matter (White and Carrol 1998). Considerable variation exists among these compounds with respect to toxicity and persistence in water or aquatic sediments. Temperature and dilution rate (*i.e.*, mixing by propellers) appear to affect volatility (*e.g.*, evaporation rate) and long-term distribution of specific compounds. Because two-cycle engine exhaust contains numerous types of hydrocarbons, analyses typically focus on effects of only the more persistent types, particularly polycyclic aromatic hydrocarbons (PAH).

Studies of Lake Tahoe suggest that localized reductions of zooplankton populations may occur in areas of high boat usage. Deleterious effects can occur both in terms of mortality and histopathological response (Tahoe Research Group 1997). Extensive laboratory tests in Sweden documented that rainbow trout exposed to typical levels of engine exhaust could be negatively affected in growth rates, enzyme function, and immune responses (Balk et al. 1994). Also, sex-specific differences were observed, which could lead to alteration of normal reproductive function. MTBE is an oxygenated additive emitted from engine exhaust that is soluble in water and does not break down readily. However, no formal Environmental Protection Agency (EPA) drinking water standards are set for this compound. Nitrous oxides contain nitrogen, which can be a limiting nutrient in aquatic systems. It is considered a small risk because of its small percentage to total atmospheric deposition rates. However, it can contribute to eutrophication. As a result, some concerned investigators have recommended restrictions on the number of two-cycle engines allowed in high usage areas of Lake Tahoe (Tahoe Research Group 1997). Similar concerns have been voiced for Lake Michigan, Isle Royale National Park, and San Francisco Bay.

Under certain environmental conditions, toxicity of some PAH compounds may increase substantially. The toxicity of PAH can be "photo enhanced" in the presence of ultraviolet light (UV) and become 50,000 times more toxic under field conditions in the presence of sunlight. When PAH are in the bodies of aquatic organisms and absorb UV light, the energized molecules or their reactive intermediates can react with biomolecules to cause toxicity that can lead to death of aquatic organisms (Allred and Giesy 1985, Holst and Giesy 1989).

Impacts to aquatic species that can be attributed to atmospheric deposition from snowmobiles have not been well studied. Field studies are extremely difficult to conduct because atmospheric deposition rates could be affected by numerous factors, including temperature, proximity to water, and combustion efficiency of individual snowmobiles. One of the more extensive studies used caged brook trout to determine effects of exhaust on fish. Exhaust components taken up by fish correlated with levels present in the environment as a result of snowmobile use (Adams 1974). Uptake of exhaust hydrocarbons and other compounds occur through the gills during respiration. It is thought that hydrocarbons are incorporated into fatty tissues, such as visceral fat and the lateral line, in a manner similar to chlorinated hydrocarbon pesticides.

Tremendous uncertainty accompanies discussion of this topic with reference to affects on aquatic resources of the GYA. The current lack of quantitative data reduces comparisons between outboard engines and anticipated effects from a specific level of snowmobile use. However, it appears reasonable that higher concentrations from emissions will likely accumulate as a result of grooming roads with the constant packing of exposed snow. These accumulated pollutants will enter adjacent watersheds during the spring melt, which generally occurs from April through June. Pollutants entering the watershed will be concentrated during this snowmelt, producing a strong "pulse" in the system. Similarly, impacts from acid rain in the eastern United States are confounded by the accumulation of the acid in snow, with subsequent melting producing a pulse of acidity in a short time and causing very low pH in many streams (Carline et al. 1992, Haines 1981).

Potential Effects

Protection of park aquatic resources and restoration of native species are primary management goals of the National Park Service. In Yellowstone National Park, groomed snowmobile roads are often adjacent to major aquatic systems (*e.g.*, Firehole River, Madison River, Gibbon River, Yellowstone River, Lewis River, and Yellowstone Lake). The Yellowstone River from the Yellowstone Lake outlet to the Upper Falls contains Yellowstone cutthroat trout. The Madison River is a potential reintroduction site for westslope cutthroat trout. The Gibbon and Madison rivers may contain fluvial Arctic grayling. Snowmobiling occurs on Hebgen, Jackson, and other small lakes located in the greater Yellowstone area. There are also areas where snowmobiles cross open water.

Hydrocarbon pollution in water may initially persist on the surface but will eventually settle into the water column, increasing exposure to fish and invertebrates. Investigations have shown dramatic increases in some contaminants in water exposed to snowmobile exhaust; some of these increases are on the order of 30 times (Adams 1974). Accumulation may also occur in sediments (Lazrus et al. 1970). Fish receive contamination from different trophic levels that are sustained in both open water and sediment environments. These pollutants accumulate in the food chain, and accumulations in fish would result in uptake by piscivorous predators including bald eagle, osprey, otter, pelican, and grizzly bear.

Physiological responses of fish to increased loads of hydrocarbons and other contaminants may increase direct and indirect mortality rates. Rainbow trout and cutthroat trout begin spawning in early spring (March through July), exposing developing embryos during this period. Research has shown that even at extremely low levels of hydrocarbon pollution, impacts may include chromosomal damage; retarded growth and development; disruption of normal biological functions, including reduced stamina for swimming and maintaining positions in streams (Adams 1974); and death.

Invertebrate vulnerability is not known; however, it is likely that early instar development may be impacted by hydrocarbon pollution entering the water. Many winter shredders (invertebrates that consume large organic debris) are emerging, mating, and laying eggs in early spring (*e.g.*, stoneflies). These developing embryos may, therefore, be more susceptible to pollutants during spring runoff periods.

Impacts of winter recreational activities on fish and other aquatic resources occur mostly where oversnow machines concentrate along groomed motorized routes and winter destination areas. In situations where snowmobiling occurs over open water (D. Trochta 1999), obvious impacts will include direct discharge into aquatic habitats. Appreciable contamination from emissions from backcountry snowmobiling probably occurs less frequently. However, dispersed snowmobile travel affects vegetation (J. T. Stangl 1999), causing erosion and damaging natural water courses and banks. Snowmobiles can cause degradation of stream and lake quality and affect aquatic species and their habitat.

Management of oversnow machine recreation should encourage the development of clean emission standards. Strict emission requirements for two-stroke engines would mitigate impacts to water quality and, subsequently, aquatic environments. Restricting motorized winter recreation near streams, lakes, and wetland habitats would minimize direct impacts to aquatic resources.

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EFFECTS OF WINTER RECREATION ON HABITUATED WILDLIFE

Little information exists on the direct and indirect impacts of winter recreation on most wildlife species. However, these effects may create potentially additive or synergistic impacts to wildlife populations (Knight and Cole 1995). Effects include energetic response to humans and human facilities, habituation to human activities, and attraction or conditioning to human foods and garbage (Herrero 1987).

Most wildlife species that become habituated or food conditioned from winter recreational activity are not protected under federal law. These include ungulate populations accustomed to winter recreationalists, roads, and snowmobile trails (Aune 1981, Meagher 1993), and carnivores, such as coyote, red fox, pine marten, that become food conditioned to human foods at recreational facilities. Bird species, including ravens, gray jays, and Clark's nutcrackers, also may become food conditioned and are protected under the Migratory Bird Treaty Act. Both black and grizzly bears have the potential to become habituated to human activities and food conditioned to human foods (Mattson 1990), but are typically not active during the winter season (Judd et al. 1986).

All wildlife species are protected in national parks (NPS 1988). On lands outside national parks, some wildlife species are subject to hunting. Most non-game bird species are protected from direct human-caused mortality by the Migratory Bird Treaty Act (U.S.C. Title 16, Section 703). Species in the Yellowstone area protected by the Endangered Species Act of 1973 (U.S.C. 1531, 1982 ammend.) include the whooping crane and peregrine falcon, which are endangered, and the bald eagle and grizzly bear, which are threatened. Whooping cranes and peregrine falcons are not considered winter residents of the Yellowstone area. Gray wolves were recently reintroduced to the Yellowstone area. While naturally occurring wolves are classified as endangered in Montana, Idaho, and Wyoming, those reintroduced into the Yellowstone and central Idaho ecosystems in 1995 and 1996 were reclassified as "experimental/non-essential populations" (USFWS 1994).

LIFE HISTORY

Many wildlife species are residents of the Yellowstone area during winter. Terrestrial species include bison, elk, mule deer, moose, bighorn sheep, mountain lion, lynx, bobcat, marten, fisher, river otter, wolverine, coyote, gray wolf, red fox, and snowshoe hare. Avian species include bald eagle, trumpeter swan, common raven, gray jay, Clark's nutcracker, great gray owl, waterfowl, raptors, and passerine bird species.

Many wildlife species migrate or become inactive during winter months. Others however, remain and adjust their foraging, habitat use, and activity patterns to winter conditions. While most winter animals are well adapted to surviving winter situations, winter environments typically create added stress to wildlife due to harsher climatic conditions and more limited foraging opportunities.

HUMAN ACTIVITIES

Winter recreation has the potential to affect wildlife foraging patterns, habitat use, and interaction with human activities. When winter recreation occurs, some wildlife species may become accustomed to people and, therefore, habituated to human activities. A further step in this process occurs when animals gain and then seek out human foods (Herrero 1985). Examples of the effect of wildlife habituation in winter recreational situations include:

1. Bison in Yellowstone National Park utilize groomed snowmobile roads as travel routes (Aune 1981, Meagher 1993).
2. Ravens converge at winter destination areas, such as developed areas and warming huts, and forage on human foods discarded or left unattended in snowmobile seat compartments and/or packs; this results in property damage.
3. Coyotes and red foxes frequent winter developments and warming huts to seek hand-outs from visitors or forage on improperly discarded food scraps. Some eventually display aggressive behavior, sometimes harming visitors. These animals are removed from the area or destroyed.
4. Areas of winter garbage storage inside and outside Yellowstone National Park attract an array of wildlife species including coyotes, red foxes, pine martens, red squirrels, ravens, magpies, and gray jays.

POTENTIAL EFFECTS

Very little information exists on specific effects of winter recreation on habituated wildlife. Moreover, the need for more specific scientific monitoring is essential to better understand the complexities of wildlife–human interactions and the direct and indirect effects that winter recreation create on wildlife populations. It is sometimes difficult to determine whether wildlife habituation can be an advantage or a detriment to populations. Studies have indicated a shorter flight distance and a higher tolerance for vehicles and humans as a result of habituation (Aune 1981, Gabrielson and Smith 1995). However, habituation can also lead to unnatural attraction to human-use areas and lead to direct management actions and subsequent human-caused mortality (Herrero 1985, Mattson 1990, Mattson et al. 1992).

Potential Opportunity Areas that will be particularly affected include:

(1) Destination areas. Highly developed destination areas may negatively impact wildlife where winter recreational sites occur in habitats that wildlife occupy. Winter destination areas are becoming more popular. These include major ski areas and park development areas, and park gateway communities. These can also be low or moderately used areas such as small residential communities and warming huts. Wildlife avoidance of habitats could occur near winter developments. However, the more obvious management concern arises when animals are attracted to developments in search of human foods.

In areas with strong bear management guidelines, such as Yellowstone National Park, a strong emphasis is placed on food storage and security (Gunther 1994). However, in winter when bears are hibernating, a lapse in food security appears more common. Managers associated with winter recreational developments should maintain high standards of food security to prevent wildlife species other than bears from becoming attracted to human facilities and foods. Garbage storage facilities should be secured from all forms of wildlife.

Planning for new winter recreational developments should include designs for animal-proof food- and garbage-storage facilities and avoid areas that could lead to animal attraction. Areas such as cooking and eating facilities, picnic areas, and garbage collection sites should be built to preclude wildlife attraction and habituation.

(2) Primary transportation routes and (3) scenic driving routes. Year-round roads may have significant effects on habituated wildlife. Primary roads may impact wildlife by creating situations where animals seek road habitats in search of food. This may occur because people feed wildlife along roadsides or, to a lesser extent, because animals scavenge dead animals killed along roads. Both types of foraging bring wildlife to roadsides and create further habituation and increase risk of mortality (Gunther et al. 1998). Wildlife managers should try to remove roadside carcasses to avoid scavengers being hit by vehicles.

(4) Groomed motorized routes. Snowmobile traffic along high- and moderate-groomed routes may pose a significant problem to habituated wildlife during the winter months. The potential for conflict could occur when animals seek groomed routes in search of food. This may occur from recreationists feeding wildlife along groomed roads or possibly with animals scavenging carcasses killed along these routes. Both types of feeding bring wildlife to groomed roadsides and create further habituation and increased risk of mortality. Wildlife managers should try to remove carcasses to prevent scavengers from being hit by over-snow vehicles.

Grooming of roads and snowmobile trails may affect ungulate movements, population dynamics, and management actions (Meagher 1993). Planning for new snow routes should avoid ungulate winter range and important wildlife habitat.

(6) Backcountry motorized areas. Ungroomed snowmobile areas may one day pose a significant habituated wildlife problem. Areas of ungroomed snowmobile use typically occur at low levels and should not attract wildlife. The potential for conflicts between wildlife and recreationists would occur when winter snowmobiling increases to higher densities and careless food security is common.

(9) Backcountry nonmotorized areas. Backcountry skiing, snowshoeing, and downhill sliding should not pose a problem to habituated wildlife. The potential for wildlife–human conflicts may occur when high-density, human winter recreational activity occurs and food security is a problem.

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EFFECTS OF HELISKIING ON WILDLIFE

Heliskiing is the use of helicopters to take skiers and snowboarders to the tops of mountain slopes that have generally been unused by other skiers or snowboarders. Typically, this activity occurs in the more remote backcountry mountains that are difficult to access by foot. Heliskiing is becoming popular in Colorado, Utah, Idaho, and Canada. Where there is snow and remote mountain slopes, there is the potential for heliskiing.

There is currently no permitted helicopter skiing use in the Greater Yellowstone Area (GYA), although a few requests have been made for permits on some forests. Some poaching (non-permitted use) does occur in the Bridger Range and may occur elsewhere.

Although helicopter skiing is not a current problem, managers need to look ahead and gather information on helicopter skiing to prevent conflicts between wildlife and heliskiers. Some managers on national forests where heliskiing now occurs state that if heliskiing is not now a permitted use in the GYA, then it should not be allowed.

Although some Potential Opportunity Areas in the GYA will not be directly accessed by skiers, the noise or sight of the helicopter will likely affect all the areas. Areas where the helicopter stages (*i.e.*, along roads, trailheads) could become a problem, and helicopters flying over wildlife winter range may affect the wintering wildlife. The Potential Opportunity Areas that will be most affected include:

- (2) Primary transportation routes
- (3) Scenic driving routes
- (6) Backcountry motorized areas
- (7) Groomed nonmotorized routes
- (8) Nonmotorized routes
- (9) Backcountry nonmotorized areas
- (10) Downhill sliding (nonmotorized)
- (11) Areas of no winter recreational use
- (12) Low-snow recreation areas

POTENTIAL PROBLEMS WITH HELICOPTER SKIING

Numerous studies have shown impacts to wildlife from low-flying aircraft, including helicopters. Studies have been conducted on birds, mountain goats, wild sheep, deer, elk, and wolverines (Knight and Cole 1995). Exposure to helicopters increases energy expenditures, reduces fat accumulation, and/or changes an animal's physiological condition (MacArthur et al. 1979). These effects may lead to reduced survivability and/or reproduction success.

Other risks associated with helicopter skiing are avalanches, mishaps with the explosives used to set avalanches, and the potential for helicopter accidents. Helicopter accidents could result in wreckage and fuel spills in pristine backcountry areas. Any of these risks could be harmful to wildlife in the wrong place at the wrong time. Impacts from recreation add to the many stresses an animal sustains during the winter and can result in changes in movements and preferred ranges, reduced foraging efficiency, decreased reproductive success, increased chance of accidents, lowered resistance to disease, and increased predation (USFS 1996).

The impacts of helicopters on individual wildlife species are described below.

BALD EAGLES AND GOLDEN EAGLES

Bald eagles exhibited various responses to aircraft depending upon encounter distance and aircraft type. Eagles responded more negatively to helicopters within 1.8 miles than to fixed-winged aircraft. If young eagles were present, the adult eagles would remain on the nest, but if no young were present, the eagles would leave the nest and sometimes attack the helicopter. Researchers found no direct evidence of adult or young eagle mortality associated with aircraft harassment (Watson 1993). Watson suggests that the use of turbine-engine helicopters may have less impact on eagles, since these helicopters are quieter than piston-driven helicopters. All aircraft should remain a minimum of 65 yards from nests and stay within the nest area for less than 10 seconds. If there is a known nesting site, heliskiing operations should not be permitted within the area of the nest.

In the Wasatch Mountains of Utah, managers have expressed concern about a helicopter skiing permit that overlaps golden eagle range. It is likely that golden eagles would exhibit responses to helicopters similar to those of bald eagles.

MOUNTAIN GOATS

Mountain goats are found in all the mountain ranges of the GYA, and heliskiing areas could overlap with important winter habitats, potentially having a negative impact on the goats. Mountain goats winter at higher elevations, often at elevations higher than 7,000 feet, on south-facing slopes with windblown ridges. They prefer to be within 1,300 feet of escape terrain. In the winter months, goats minimize their movements, foraging during the warm parts of the day, decreasing energy expenditures.

A study of the effects of helicopter disturbance from mining activities showed some adverse impacts to mountain goats (Côté 1996). Côté found an inverse relationship between the goat's response to the altitude of the helicopter above the animal. He believes that mountain goats are more sensitive than other open-terrain ungulates. Goats responded most negatively when the helicopter was within 540 yards. Animals did not habituate to repeat overflights and responded in the same manner whether it was the first flight of the day or subsequent flights. When a helicopter was present in an area for many hours, the goats remained alert during the entire period and did not forage. Helicopters at close range caused mountain goat groups to split apart, and in some cases animals became injured. Côté recommends that a 1¼-mile buffer be placed around mountain goat herds to decrease the harmful effects of helicopters on the goats.

Similar negative impacts to goats were discussed in the environmental assessment of helicopter skiing on the Ketchum Ranger District of Idaho (USFS 1996). The biological assessment found that mountain goats ran when the helicopter was within 1/3 mile. Joslin (1986) noted that mountain goat behavior was changed negatively in response to helicopters used for seismic exploration. A study on the Beartooth Plateau, Montana, recommended that snowmobiles not be permitted within one mile of goat habitat (Haynes 1992); a similar recommendation should be made for helicopters.

If helicopter skiing is ever permitted in the GYA, mountain goat winter and spring ranges should be avoided.

ELK

Elk wintering at high elevations or along the route that a helicopter travels may be negatively affected by the aircraft because of increased energy expenditures in response to the disturbance. In the environmental assessment of helicopter skiing in the Ketchum Ranger District (USFS 1996), elk were identified as a species of concern.

BIGHORN SHEEP

Helicopter skiing would affect bighorn sheep in the same manner that it would affect mountain goats and elk. Jorgensen (1988) documented that bighorns abandoned winter range during the 1988 Winter Olympics. Helicopter flights, avalanche blasting, and human activity on ridge tops pushed the resident sheep to less optimal habitats. Bighorns are also negatively affected in the Grand Canyon as a result of helicopter overflights (Stockwell and Bateman 1991).

WOLVERINES

Female and male wolverines range 238.5 square miles and 983 square miles, respectively. Females den from mid-February through April. Den habitat is in subalpine, north-facing cirques with large boulder talus. This type of habitat is similar to the type of area used by heliskiers. Wolverines are sensitive during the denning periods, and females have been known to move their kits if people or human tracks are near the den site. Wolverines and helicopter skiing were discussed in the environmental assessment of helicopter skiing in the Ketchum Ranger District (USFS 1996). Heliskiing should be avoided in areas where wolverines are known to occur, especially if the activity is near denning habitat.

OTHER WILDLIFE

Many other species of wildlife could be negatively affected by helicopter skiing. Wolves and other carnivores may be impacted if prey species, such as elk, alter their behavior because of helicopter presence. There could be a positive result for predators if their prey becomes more susceptible to predation. Peregrine falcons may be bothered in the springtime during the breeding period if helicopter skiing is occurring in their territory. It is unknown how heliskiing might affect the lynx.

THE EFFECTS OF NOISE ON WILDLIFE

Knight and Cole (1995) examined the effects of noise on wildlife and found that noise from helicopters could be damaging to animals. Wildlife exposed to loud noises show an elevated heart rate. Noise can harm the health of an animal by altering reproduction (loss of fertility, harm during early pregnancy), survivorship, habitat use and distribution, abundance, or by interrupting torpor or hibernation. Animals may develop an aversion or avoidance response and show high levels of antagonistic behavior and decreased levels of food intake in areas with chronically loud noise. Animals may show signs of either acute or chronic hearing loss that could lead to masking other life-threatening noises, such as the approach of a predator. Wildlife abandonment of preferred habitat and the repeated reaction to avoid inescapable noises may lead to an increase in energetic expenses.

MANAGEMENT GUIDELINES

Heliskiing use should be limited to the minimal amount of area possible, and overflight distances should be more than 1,000 feet above and 2 miles away from sighted wildlife or known wildlife winter habitat. Managers should overfly proposed heliskiing areas to determine locations of wildlife and prohibit skiing where conflicts would occur. The permittee should be required to notify managers of any wildlife sightings as well as the areas that were used. Managers should have the authority to close any area that is in question. There should be no overflights or use of slopes with known wolverine dens. The use of explosives to set off avalanches should be limited, and any wildlife or human presence should be ascertained before use.

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HARASSMENT OF WILDLIFE BY THE PETS OF WINTER RECREATIONISTS

Harassment of wildlife by the pets of winter recreationists is increasing. Harassment is defined as any activity of humans and their associated domestic animals that increase the physiological costs of survival or decrease the probability of successful reproduction of wild animals. As winter recreational use increases and as people continue to take pets with them on their winter trips, the problem will continue to grow. The literature suggests that the primary problem is dogs chasing deer, but dogs can chase other wildlife, and cats can kill birds and small mammals.

Harassment of wildlife by pets is primarily occurring on national forest lands in the Greater Yellowstone Area (GYA) as pets are not allowed off-leash in the national parks. The extent of the problem in the GYA is unknown at this time.

POTENTIAL PROBLEMS WITH PET HARASSMENT OF WILDLIFE

Pets both chase and kill wildlife (George 1974, Lowry and McArthur 1978). In a 1958 study, mule deer in Missouri were chased from their home ranges by dogs, including one chase that lasted 3.25 miles (Progulske and Baskett 1958). This study also stated that dogs were a negligible cause of direct mortality of deer under the conditions of the study. Bowers (1953), however, found that free-running dogs killed more deer than legal hunters during a two-month winter period in Virginia.

In Yellowstone National Park in the summer of 1989, a domestic dog chased and caught a mule deer buck and tore off the deer's lower mandible. Park rangers subsequently destroyed the deer.

Being chased by a domesticated pet can disrupt a wild animal's energetic balance. Geist (1971) stated that running increases an ungulate's need for food and that these animals can become stressed to the point that they require more energy than they are able to take in. Consequently, the animals must use body reserves. Pregnant animals suffer higher stress levels, causing some animals to abort. A controlled study in Virginia (Gavitt 1973) used dogs to intentionally chase deer. The study found no significant differences in fawns per doe survival rates between deer that were chased and deer that were not chased. The study also found no changes in home range and that no healthy deer were caught by dogs.

Even if a direct chase does not occur, domestic pets can increase stress on wildlife. MacArthur et al. (1982) found that the greatest increase in bighorn sheep heart rates occurred when the sheep were approached by humans with a dog.

The literature suggests that deer are the primary target of harassment by pets and that dogs are the primary problem. But, cats have been implicated in killing a snowshoe hare (Doucet 1973) as well as birds and small mammals.

It is possible for domestic pets to transmit diseases to wildlife. Canine distemper, a severe and highly contagious virus, can be transmitted to both canids and mustelids. Transmission is primarily by aerosol or by direct contact with infected individuals. Mortality rates from canine distemper vary between species and range from 20–100 percent (Wyoming Game and Fish Department 1982). Yellowstone National Park has had one wolf and one pine marten mortalities from canine distemper (Douglas Smith, personal communication). Parvovirus is also a disease concern. In Isle Royale National Park, 25 wolves died in two years from a parvovirus epidemic that was most likely introduced from a domestic dog (Jack Oelfke, personal communication). Transmission is only a problem in dogs that have not been properly vaccinated.

MANAGEMENT RECOMMENDATIONS

Visitor education has the most promise for mitigating this potential problem. Informing people of the potential problem and asking them to leash pets in critical deer winter range could reduce chasing of wildlife. Direct restrictions on pets in critical deer winter range could be applied if educational efforts are not effective.

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EFFECTS OF SNOWMOBILING ACROSS OPEN WATER ON FISH AND WILDLIFE

Snowmobiling on open water involves a daring or, in some cases, intoxicated snowmobiler with a powerful machine who attempts to either make it across open water or to take a round trip on open water without submerging the snowmobile. If the snowmobile is submerged, the snowmobiler will hook onto it with a rope or chain and pull it out of the water using another snowmobile on the bank.

Snowmobiling on open water has the potential to affect water quality; aquatic species, such as invertebrates and trout; and riparian-dependent wildlife, specifically moose, furbearers, waterfowl (including trumpeter swans), and bald eagles.

This activity is currently not widespread in the Greater Yellowstone Area (GYA), but has occurred in a few isolated areas (the author has personal knowledge of the activity occurring on the Henrys Fork at Mack's Inn, Idaho, and D. Welch of the U.S. Forest Service has observed snowmobiles crossing open water on Island Park Reservoir). There is potential for this type of activity to increase because of its popularity in other parts of the country.

The most desirable waters for this activity are shallow ponds or shallow slow-moving streams with a gradually sloping bank where the machine can either exit or be retrieved if submerged. If the snowmobiler engages in this activity on a regular basis, it is desirable to choose locations near a facility where the wet snowmobiler can warm up and dry off.

Most waters in the GYA (lakes, ponds, and streams) are frozen throughout the winter period. However, some spring-fed streams, thermal waters, and areas where a stream empties into a lake or reservoir may remain open during part or all of the winter. Because the amount of open water is limited in the GYA during winter, it is critical to the survival of many wildlife species.

POTENTIAL EFFECTS

Snowmobiling on open water has the potential to pollute the water with snowmobile exhaust and spilled oil and/or gas, to stir up sediments on the bottom, to disturb winter-stressed fish and other aquatic wildlife, and to displace wildlife from important winter habitat. Bald eagles forage along open water, and waterfowl use open water for foraging and loafing during the winter. Moose use open water for foraging and travel and find security in the associated riparian vegetation. Several furbearers use open water and associated riparian vegetation during the winter.

A literature search produced little information on the effects of snowmobiling on open water. Adams (1975) found that lead and hydrocarbons from snowmobile exhaust were in the water at high levels during the week following ice-out in a Maine pond. Fingerling brook trout in the pond showed lead and hydrocarbon uptake. Stamina, as measured by the ability to swim against the current, was significantly less in trout exposed to snowmobile exhaust than in control fish. Gabrielsen and Smith (1995) found that fish stopped swimming in response to ground or sound vibration.

In the GYA, the Potential Opportunity Areas that will most likely be affected by snowmobiling on open water include:

(1) Destination areas
(2) Primary transportation routes
(12) Low-snow recreation areas

MANAGEMENT GUIDELINES

Agency managers need to be aware of the potential for snowmobile use on open water and that there are possible effects to water quality, fish, and wildlife. This activity is in defiance of common sense, and agencies should prohibit it on public land to avoid impacts to water quality, aquatic species, and riparian-dependent wildlife.

To maintain water quality, Bury (1978) suggests a shift to four-cycle engines in snowmobiles. Four-cycle engines produce less pollutants. Shea (1979) recommends that snowmobile trails be routed away from river courses to protect wintering swans.

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